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Multilayer planar array radiators compatible with digital beam forming array

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Abstract Multilayer planar array radiators are well suited as part of a digital beam forming antenna, because they can be easily integrated, with active elements in multilayer structure. This forms the basis for futuristic highly integrated circuits to be used in terminals for satellite communication system. In these antennas feeding network should be capable to efficiently transfer the signal from radiator to the underneath RF circuit in multilayer configuration or vice-versa. 5 × 5 array of circularly polarized aperture coupled radiators is designed and developed in L-band. Feeding network to generate circular polarization is realized in tri-plate configuration. Symmetric tri-plate configuration is used in order to provide efficient coupling to radiator as well as underneath RF circuit. Digital beam forming antenna configuration, detail design of tri-plate fed aperture coupled patch antennas and tri-plate to microstrip aperture coupled transition along with their analyzed and test results are presented in this communication.

Keywords Planar array antenna, digital beam configuration

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1. Digital beam forming antenna configuration

Digital beam forming antenna is based on capturing the radio frequency signals at each of the antenna elements and converting them into two streams of binary base band signals *i.e.*, in-phase (I) and quadrature-phase (Q) channels. Digital base band signals include amplitude as well as phase of the signal received at the elemental level of the array [1].

The beam forming is carried out, by weighting these digital signals, thereby adjusting their amplitude and phases such that when added together they form the desired beam. This process is carried out using a special-purpose digital signal processor. Figure 1 depicts the configuration of the digital beam forming antenna. It consists of planar array of aperture coupled patches with radome, triplate feeding network, RF circuit board including calibration and LO-distribution circuits, IF and ADC circuit board and digital down converter board [2]. As antenna feeding network, RF circuit, LO circuit board, and other circuits boards are in triplate configuration, therefore antenna should have very low back radiation in order to avoid parallel plate modes in triplates. Mutual coupling between patch elements, feeding network elements, RF circuits, and LO circuit elements is required to be minimised in order to provide accurate translation of amplitude and phase information available at each patch element to the corresponding channel digital regime.

2. Planar array antenna

Planar radiators are well suited as part of a digital beam forming antenna because they can be easily integrated with active elements in multilayer structures. Extensive investigations were carried out determining number and distance of the patches to achieve the required gain of minimum 10 dB at 75° for scan angles up to 60° and to avoid grating lobes. A viable compromise has been found in designing a 5 × 5 array with aperture coupled patches at $\lambda_0/2$ distance (Figure 1).

3. Symmetric triplate fed patch antennas

In digital beam forming antennas the integration of planar array antenna with active circuits in multilayer configuration makes the overall antenna compact and reduces the losses.

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Feeding circuits in such antennas are required to capture RF signals from patches and to couple them to the underneath

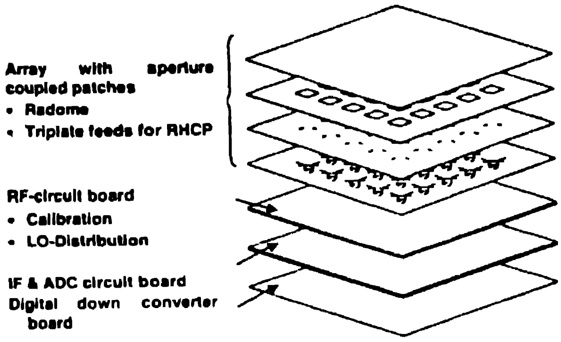

Figure 1. Digital beam antenna configuration

RF circuits at the elemental level. Feeding network in symmetric triplate configuration is preferred in the development of these antennas. However the triplate configuration allows the parallel plate modes to exist in the feed circuit layers, which are excited at the slot discontinuity in the upper ground plane and reduces the overall antenna efficiency. Parallel plate modes can be suppressed using shorting pins around the slot but it makes the fabrication process quite complex [3]. To suppress the parallel plate modes Yamamoto and Itoh [4] have given a new approach in case of linear polarisation. Here, this technique is extended for the development of circularly polarised aperture-coupled patch antennas. Under this technique, effect of coupling slots on the resonant frequency of the patch are reduced by selecting very small size coupling slot and impedance matching is achieved by using shunt stub as shown in Figure 2.

Square patch is excited with a perpendicular slot arrangement, and required RHCP with cross polarisation below −15 dB is performed with a 3-dB branch line-coupler in symmetric triplate technology. Antenna configuration and the used substrates are shown in Figure 2. Very small size non-resonant slots ($<\lambda_0/6$) are used along with shunt stubs in order to suppress inevitable parallel plate modes. Commercial, MoM based codes [5,6] are used to simulate multilayer structures. Measured RHCP and LHCP radiation characteristics of the developed antennas in L-band are shown in Figure 3.

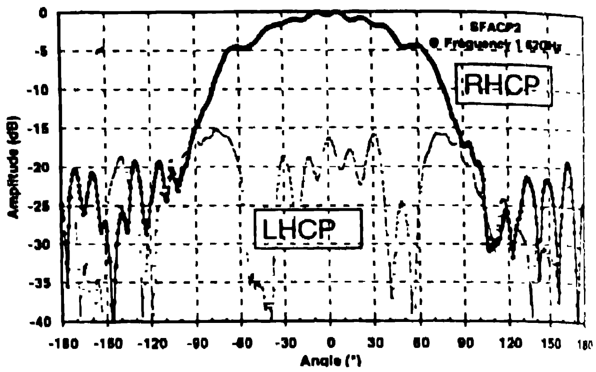

Figure 3. Measured RHCP and LHCP radiation characteristics of antennas in L-band

4. Symmetric triplate to microstripline slot coupling

In order to couple power from feeding network to underneath RF circuits, symmetric triplate to microstripline slot coupling is investigated without using shorting pins around the slot Very small size non-resonant slot is used along with shunt stub in triplate circuit. It is observed, that using conventional

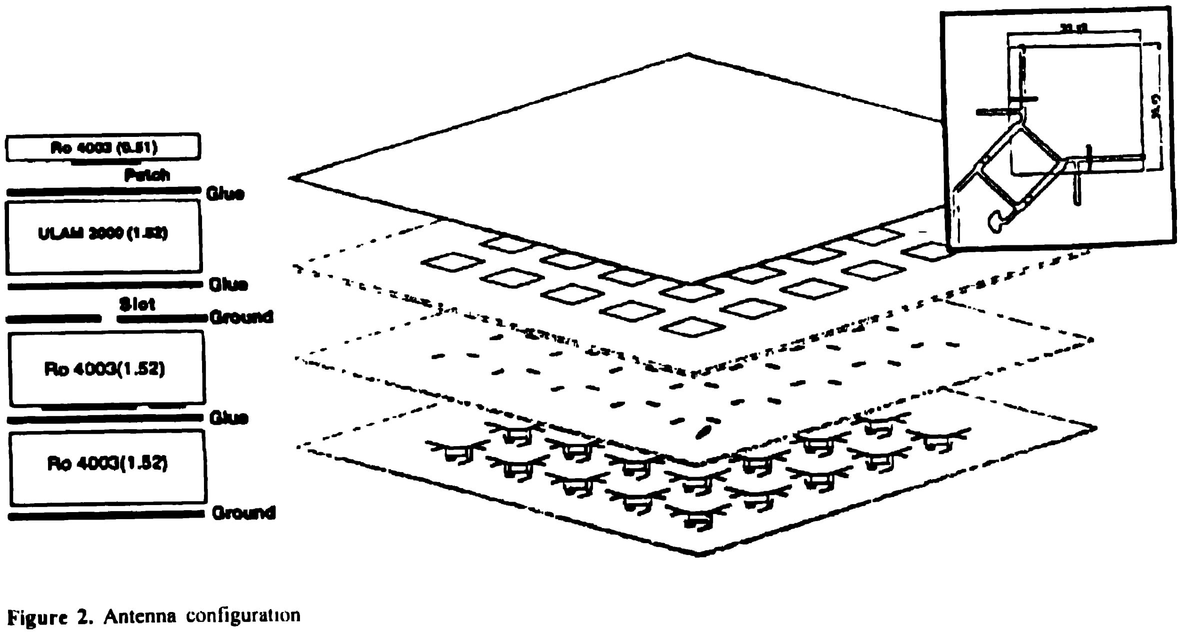

Figure 2. Antenna configuration

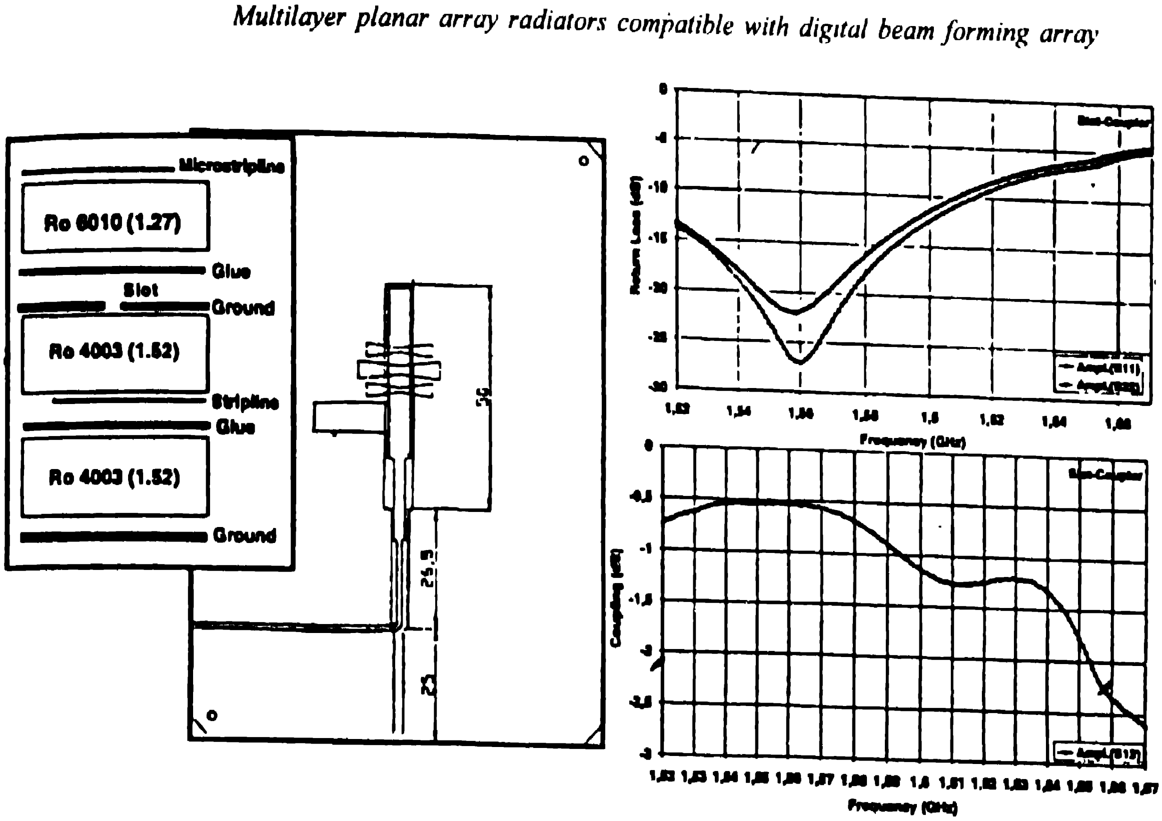

Figure 4. Triplate to microstrip configuration with measured performance

50 Ω transmission lines, the coupling loss remain around -2 dB even under highly impedance matching conditions. Rigorous analysis on MoM based codes, is carried out using different impedance lines and drastic improvement in coupling is observed using low impedance lines. Loss is further reduced using tri-slot in place of single slot as depicted in Figure 3.

By optimising the size and position of the additional slots on both sides of the central one, high order of impedance matching as well as reduction in coupling loss are achieved. Quarter wave transformers are used to match the 20 Ω impedance lines to conventional 50 Ω output lines

5. Results and conclusion

Developed symmetric triplate fed multilayer planar array is compatible in the digital beamforming antennas. Figure 3 depicts the measured radiation characteristics of single radiator. It provides 5.5 dBiC gain of single radiator. A new slot-coupled technique from symmetric triplate to microstripline is presented. Measured return loss and coupling is shown in Figure 4. Return loss better than -20 dB and coupling loss about -0.5 dB are achieved. Measured results confirmed the effective performance of the proposed geometry. This coupling arrangement can be useful in the multilayer active or DBF antennas.

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